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I, Kenji MIWA, of 2-1030, Umemorizaka, Meito-ku, Nagoya-shi, Aichi 465-0065 Japan

am one of named inventors of U.S. Application Serial No. 09/158,099 and I hereby declare that the following is a certified translation of the priority document.

(Signature of Inventor) Kenji Miwa

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[TITLE OF THE DOCUMENT] SPECIFICATION

[TITLE OF THE INVENTION] METHOD OF REFINEMENT OF MICROSTRUCTURE OF METALLIC MATERIALS

[PATENT CLAIMS]

[Claim 1] A method for refining microstructure of metallic materials, characterized in that comprises forming cavitation (cavities) in molten metal by the direct application of high-energy vibrating force such as electromagnetic vibrating force, ultrasonic vibrating force to the molten metal, crushing the resulting solid metal crystal particles into small pieces by the impact pressure generated during the collapse of the cavities, and yielding a refined microstructure thereof.

[Claim 2] The method for refining microstructure of metallic materials according to Claim 1, wherein the high-energy vibrating force is applied during the solidifying process of the molten metal.

[Claim 3] The method for refining microstructure of metallic materials according to Claim 1 or 2, wherein the application of the high-energy vibrating force to a metal in the solidifying process is performed by impressing an electric current and a magnetic field simultaneously to the molten metal or the solidifying metal.

[DETAILED EXPLANATION OF THE INVENTION]

[0001]

[Technical Field in Which the Invention Is to be Utilized]

This invention relates to a method for refining a

microstructure of metallic materials. More particularly, the present invention relates to a method of refinement of microstructure of metallic materials characterized in that allows microstructure of metallic materials to be refined irrespective of the type of metal or refining agent, wherein high-energy vibration force such as electromagnetic vibrating force, ultrasonic vibrating force, or the like is applied directly to molten metallic materials.

[0002]

[Description of the Background Art]

Methods for refining microstructure of metallic materials are broadly classified into two types such that methods in which refining agents are added to molten metallic materials to refine the microstructure of the metallic materials solidified, and methods in which the solid metallic materials are subjected to processing processes and heat treatments to refine the microstructure thereof.

[0003]

Specifically, in the methods of the first group, refining agents act as nuclei for the solid metal crystal particles to be formed during solidification, yielding a refined microstructure that corresponds to the dispersion state of the refining agents, whereas in the methods of the second group, microstructures refined are obtained by recrystallization of the metals generated by heat treatments after the processing processes such as rolling, extrusion, or the like.

[0004]

In the methods of the first group, however, a close crystallographic relationship to be achieved between the refining agent and the solid crystal particles is required in order to allow the refining agent to be effective, and there is many cases where it is impossible to obtain adequate refining agents for some types of metals.

In addition, the refined structure which is smaller than the particle size of the refining agent cannot be made.

[0005]

In the methods of the second group, it is difficult to yield adequate refining because the processing processes such as rolling, extrusion and the like have limitation in their effects, and when the processing processes exceed the limitation, fracture of the structure of the metal causes, and there is a tendency to cause metals recrystallized as well as metal particles enlarged as a result of the heat treatment after the processing processes.

An urgent need therefore existed for developing a novel method for refining microstructure of metallic materials that would be able to solve the above-described problems of the conventional methods.

[0006]

[Subject to be Solved by the Invention]

An objective of the present invention is to overcome these subjects.

Specifically, an objective of the present invention is to provide a novel method for refining microstructure of metallic materials that is capable of refining the microstructure thereof irrespective of the type or composition of the metallic materials.

Another objective of the present invention is to provide a method for refining microstructure of metallic materials that facilitates refining easily even for metals being difficult to be refined in the past.

【0007】

【Means of the Solution to the Subject】

The following technological means are employed in the present invention, which is aimed at overcoming the aforementioned subjects.

(1) A method for refining microstructure of metallic materials, characterized in that comprises forming cavitation (cavities) in molten metal by the direct application of high-energy vibrating force such as electromagnetic vibrating force, ultrasonic vibrating force to the molten metal, crushing the resulting solid metal crystal particles into small pieces by the impact pressure generated during the collapse of the cavities, and yielding a refined microstructure thereof.

(2) The method for refining microstructure of metallic materials according to (1) above, wherein the high-energy vibrating force is applied during the solidifying process of the molten metal.

(3) The method for refining microstructure of metallic materials according to (1) or (2) above, wherein the application of the high-energy vibrating force to a metal in the solidifying process is performed by impressing an electric current and a magnetic field simultaneously to the molten metal or the solidifying metal.

[0008]

[Details of the invention to be practiced]

The present invention will now be described in detail.

The present invention of this application is characterized in that the microstructure of metallic materials is refined by the direct application of high-energy vibrating force to them. In this circumstance, it is important to apply electric current and magnetic field simultaneously as the high-energy vibrating force, whereas it is impossible to cause significant effect on the fine microstructure of metallic materials, by applying the electric current or magnetic field alone, because the electromagnetic vibrating force is Lorentz Force that can only be generated when an electric current and a magnetic field are applied simultaneously.

As the high-energy vibrating force, electromagnetic vibrating force on ultrasonic vibrating force is exemplified as preferable examples, but these examples are not all-encompassing and all other types of forces capable of applying the high-energy vibrating force on molten metal in the same manner can be used.

The high-energy vibrating force is applied to molten metal, and in this circumstance, the high-energy vibrating force is preferably applied to solidifying metal.

As used herein, in the present invention, the term "molten metal" refers to a metal that is completely liquefied at a temperature above its melting point. In addition, the term "solidifying metal" refers to a metal in which solid metal crystals are just occurring in a molten metal at a temperature below its melting point.

The present invention can be adequately applied, for example, to aluminum alloys such as Al-Si alloys or magnesium alloys, and the present invention can be applied, irrespective of any refining agent or metal to be used, and in particular, there is no dependence on the type or composition of metal.

[0009]

The high-energy vibrating force is applied to a solidifying metal in accordance with the above-described method, thereby cavitation (cavities) is caused in the molten metal and the resulting solid metal crystal particles are destroyed and decomposed into small pieces to generate the refined solid metal particles according to the impact pressure generated during the collapse of the cavities.

[0010]

Because the cavitation is induced while some of the metal is still in the molten state, not only the newly formed solid metal crystals are destroyed and divided into pieces but also

the already existing solid metal particles are destroyed and divided into pieces by applying high-energy vibrating force until the molten metal has completely solidified, thereby it is possible to obtain a refined microstructure thereof.

A solidified microstructure of metallic materials can therefore be refined as well.

[0011]

The high-energy vibrating force should be applied during (in the process of) solidification of the metallic materials. It is difficult to form cavitation (cavities) when high-energy vibrating force is applied to metallic materials after solidification thereof, and therefore, after solidification, there is a possibility that the solid metal crystal particles will not be destroyed and divided into pieces.

[0012]

In addition, in this invention, even metals that are difficult to be refined by conventional methods can be readily refined because the refining effect of this invention by the high-energy vibrating force does not depend on the type or composition of the metal.

By the method for refining microstructure of metallic materials wherein the high-energy vibrating force is applied in accordance with the present invention, for example, silicon crystals as initially crystallized particles in a hyper-eutectic aluminum-silicon alloy can be refined to crystal particles with diameter of 0.5-3.0 μm level.

[0013]

[Example]

The present invention will now be described in detail through examples thereof, but the present invention is not limited by these examples.

Fig. 1 shows an example of the apparatus for implementing the present invention. In the drawing, 10 is a metal sample, 11 is an electrode which is disposed in contact therewith, and 12 is an electromagnetic coil which is disposed such that it envelops the metal sample.

[0014]

When an alternating current of about 80 A is applied to the metal sample via the electrode, the metal sample is melted by Joule heat generated, and the temperature of the metal sample reaches a prescribed temperature. The temperature of the molten metal sample is then lowered and solidification of the molten metal sample is started by reducing amount of the electric current. An electromagnetic vibrating force which is created based on the alternating current and the direct current magnetic field caused by applying a direct current magnetic field of 1.4 T (Tesla) through the intermediary of the electromagnet 12, and thereby the molten metal sample is vibrated. As a result, cavities are formed in the metal sample, and the solidified metal crystals are destroyed and decomposed by the cavitation generated.

[0015]

The above-described apparatus was used to impose the electromagnetic vibrating force upon a solidifying alloy in the form of a hyper-eutectic Al-17% Si alloy. The results are shown in Table 1. As shown in Table 1, it was found that the silicon particles as initially crystallized particles could be refined remarkably into small pieces.

[0016]

[Table 1]

		Crystal particles diameter (μm)
Example of present invention	Introduction of high vibrational energy	0.5 - 3
Conventional example	Use of refining agents	30 - 50

[0017]

Examples of the present invention have been described in detail above, but these examples merely serve as an illustration, and the same effect can be achieved for other metals, alloys, intermetallic compounds, semimetals, nonmetals, and the like. The present invention allows embodiments incorporating various changes based on the knowledge possessed by those skilled in the art to be implemented as long as these changes remain within the scope of the present invention.

[0018]

[Effect of the Invention]

The present invention relates to a method for refining microstructure of metallic materials characterized in that comprises forming cavitation (cavities) in molten metal by the direct application of high-energy vibrating force such as electromagnetic vibrating force, ultrasonic vibrating force to the molten metal, and destroying and dividing the resulting solid metal crystal particles into small pieces by the impact pressure generated during the collapse of the cavities, and yielding a refined microstructure of the metal. The present invention allows microstructure of metallic materials to be readily refined to the level of fine particles without the use of refining agents and without any relation to the type or composition of the metal.

[BRIEF EXPLANATION OF THE DRAWING]

[Fig. 1]

Fig. 1 is a schematic view illustrating an example of an apparatus suitable for implementing the present invention.

[Description of marks]

10 metal sample

11 electrode

12 electromagnetic coil

[TITLE OF THE DOCUMENT] ABSTRACT

[ABSTRACT]

[SUBJECT] The present invention provides a method for refining microstructure of metallic materials.

[MEANS OF SOLUTION] The present invention relates to a method in which cavitation (cavities) is formed in molten metal by the application of high-energy vibrating force to a metal in the process of solidification, and the newly formed solid crystal particles are destroyed and decomposed by the impact pressure generated during the collapse of the cavities to refine the microstructure of the material. High-energy electromagnetic vibrating force is applied to the solidifying metal sample by applying an electric current and a magnetic field simultaneously in the apparatus comprising the electromagnet 12 for applying a direct current magnetic field and the electrode 11 for applying an alternating current to the metal sample 10, thereby the solid crystal particles are destroyed and decomposed into small pieces, and a fine microstructure thereof is yielded.

[SELECTED DRAWING] Fig. 1

【TITLE OF THE DOCUMENT】 DRAWING

【Fig. 1】